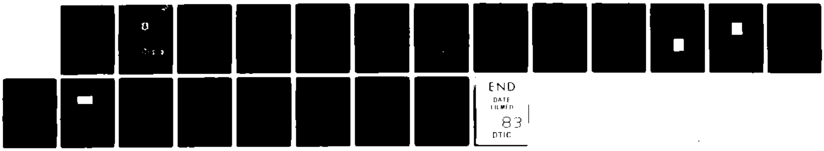
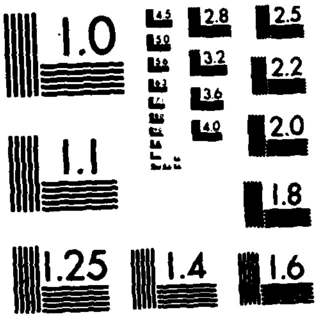
AD-A123 934 ACTA ELECTRONICA SINICA (SELECTED ARTICLES)(U) FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH S LIN ET AL. 10 DEC 82 FTD-ID(RS)T-0982-82 1/1

UNCLASSIFIED F/G 20/5 NL



END
DATE
FILMED
83
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

2

FTD-ID(RS)T-0982-82

AD A123934

FOREIGN TECHNOLOGY DIVISION

ACTA ELECTRONICA SINICA

(Selected Articles)

DTIC FILE COPY

DTIC
S ELECTE D
JAN 3 1 1983
D

Approved for public release;
distribution unlimited.

83 01 31 148

FTD-ID(RS)T-0982-82

EDITED TRANSLATION

FTD-ID(RS)T-0982-82 10 December 1982

MICROFICHE NR: FTD-82-C-001647

ACTA ELECTRONICA SINICA (Selected Articles)

English pages: 16

Source: Dianzi Xuebao, Vol. 9, Nr. 5, September 1981, pp. 70-78

Country of origin: China
Translated by: LEO KANNER ASSOCIATES
F33657-81-D-0264
Requester: FTD/TQTD
Approved for public release; distribution unlimited.

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

DTIC COPY INSPECTED 2

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

Table of Contents

GRAPHICS DISCLAIMER

All figures, graphics, tables, equations, etc. merged into this translation were extracted from the best quality copy available.

STUDY OF THE X-RAY PREIONIZED ELECTRON AVALANCHE DISCHARGE LASER AT HIGH GAS PRESSURES*

by Lin Shaoji (University of California, San Diego) and
Bao Zhixiang, Gong Guangyuan, Huo Yunsheng, Shu Juping,
Tang Shiqing, Wei Yunrong, Zheng Chengen (Shanghai Institute
of Optics and Fine Mechanics, Academia Sinica)

Abstract

This paper represents some test results of an x-ray preionized avalanche discharge laser. In this device, a water dielectric transmission line is employed as the discharge energy source and a multi-arc-channel rail gap switch is used to improve the front edge characteristics of the discharge voltage. Homogeneous discharge lasted about 70 ns in a typical XeCl* laser discharge gas of 2-5 atm, and XeCl*3080Å laser output energy (5-6J/l exceeding 1.2J was obtained in an active volume of $2x1.5x70\ cm^3$.

I. Preface

Use of x-ray preionization to obtain electron avalanche homogeneous self-sustained discharge has already been experimentally proven to be a feasible method [1-3]. This preionization method possesses different special features for electron beam and ultraviolet light preionization. Therefore, since it has come out it has received a good deal of attention.

Firstly, x-rays possess strong penetration capabilities for substances. For an atm pressurized inertia gas halide laser

*Received August, 1981.

discharge gas or CO_2-N_2 laser discharge gas, the range of the 300keV high energy electron beam is about 20 cm and that of ultraviolet photons is about 10cm. However, the 1/e strength attenuation length of 200 keV photon energy x-rays are 50 and 110 m in an atm pressure Ar or Ne [3]. Because of this, use of x-ray preionization easily attains relatively homogeneous preionization in high gas pressure large volumes. Secondly, because the x-ray energy loss when in a substance with a low penetration atom ordinal is much smaller than with high energy electrons, when developing toward high repetition discharge, this preionization method simplified some of the technical problems related to the thermal diffusion of the window. Therefore, study of the electron avalanche homogeneous self-sustained discharge produced by x-ray preionization has certain real significance. This paper takes the HCl-Xe-He(or Ne) discharge system as an example to present certain of our research results concerning this area of work.

II. Test Equipment and Parameters

The test equipment was composed of an x-ray generator, discharge chamber, water transmission line, discharge loop and rail gap switch as shown in fig. 1.

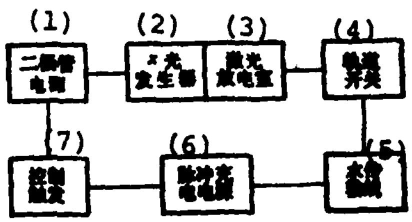


Fig. 1 Block Diagram of Equipment

Key: 1. Diode source
2. X-ray generator
3. Laser discharge chamber

Key: 4. Rail gap switch
5. Water transmission line
6. Pulse charge source
7. Control trigger

The situation of each part is as follows:

1. The x-ray generator: remodeled from a cold cathode electron gun with diode type large area emission. The cathode is composed of five pieces of tantalum foil placed side by side with thicknesses of 0.01mm, distances of 1cm and lengths of 74cm. The four sides are enclosed with stainless steel screen covering. The anode is situated 5.5cm directly in front of the cathode and is made from large area tantalum foil with a thickness of 0.015mm. The diode source is a five level Marx generator with output voltage of (-100) to (-170)kV and output capacitance of 0.09μF. The high energy electrons emitted from the cold cathode are transmitted on to the anode tantalum foil wherein large area bremsstrahlung radiation is produced. The x-ray output window is located behind the anode tantalum foil. It is composed of two large areas both of which are arranged on a 37x5cm^2 rectangular window. 0.1 mm thick polyester thin film is used to seal the window so as to separate the diode's vacuum chamber and discharge chamber.

2. The laser discharge chamber: the cathode of the discharge chamber is stuck on the 0.5mm thick flat aluminum plate outside the x-ray output window. The anode is a brass electrode with a suitable surface. It is fixed on an organic glass cover plate and passes a brass rod with a diameter of 8mm through the cover plate so as to connect the anode and outer discharge transmission line. The inductance induced by this type of feed connection mode is about 6nH. The distance between the cathode and anode is 2cm and the discharge length is 70cm. Integrated photographs of the discharge area show that the discharge width is about 1.6cm.

The laser resonant cavity used an internal cavity structure and steady cavity oscillation mode, and the cavity length was 1m. The entire reflection terminal used multilayered dielectric film or an aluminum plated reflector with about 90% reflectivity. The laser output terminal used a multilayered dielectric film quartz reflector with 3080Å penetrating 10%-25%. When there is high energy output, a quartz reflector which does not have a plated film layer is most often used.

3. The water transmission line: composed of three nickel plated aluminum plates with areas of $120 \times 80 cm^2$ and distances of 2.5cm. They are submerged and joined in deionized water (which is used as the discharge source). The characteristic impedance of the entire transmission line is 0.6Ω and the total capacitance is 52nF. The pulse source for the water transmission line charge is a two level Marx generator.

4. The discharge loop and rail gap switch: a multi-channel rail gap switch is joined between the water dielectric transmission line and the discharge chamber. It can effectively improve the front edge characteristics of the discharge voltage. Under a $XeCl^*$ laser discharge gas with 2 atm pressure, actually measured pulse rise time $\tau_r < 20ns$. There is impedance matching carried out as much as possible between the water transmission line and rail gap switch as well as between the rail gap switch and discharge chamber. Aside from specific cases, it is always maintained at 0.6Ω.

During operation, we first trigger the electron gun's Marx generator so that x-rays begin to be generated. At the same time, a high pressure pulse signal comes out of the first line of the Marx generator and triggers the pulse charge source's switch after cable transmission causing it to begin charging the water dielectric transmission line. When the charge reaches a certain

voltage level, the rail gap switch conducts it through and the discharge voltage follows it and is added on to the discharge chamber's anode. The proper regulation of the charge source's coupling parameters can cause the discharge to be carried out under gas with charged preionization conditions.

III. Test Results and Discussion

1. X-Ray Preionization

Test results of the electron gun diode's pulse current and voltage indicate that the time total width of the effectively accelerated high energy electrons is 1.5 μ_s. Time integral tests for intense radiation were completed by a heat release component (LiF monocrystalline piece). Results indicated that in the laser discharge area x-ray strength was the quantitative level of each pulse 10^2mR (milliroetgen).

To estimate the size of the x-ray preionization effect, S. Sumida et al [4] used the x-ray average energy method. Processing was carried out by approximating the x-ray strength of the continuous spectrum distribution as the monochromatic source. This paper roughly estimated using a similar method. Based on experiments, we can basically equate the x-ray strength of this device as the monochromatic source of 25KeV. Afterwards, based on the absorption coefficient of the discharge gas, we can find the ratio of ionization to the number produced in unit time, unit volume and when the x-ray passes through gas and air (S_L/S_{Air}) for the gas pressure and mass ratio of each type of gas as well as the average energy required to produce a pair of electrons or ion pair in these gases [4]. When the x-ray strength is 10^2-10^3mR, we can obtain $S_L \approx (10^{15}-10^{16})$ pair/cm^3 for typical XeCl* laser mixed gas with 2 atm pressure. From this, we can estimate preionization electron density $n_e \approx (10^8-10^9)$ single/cm^3.

2. Discharge Characteristics and Synchronization

Tests results of discharge voltage and current show that an approximately 70ns quasi-steady state process exists in the discharge process. This time is close to the wave propagation time provided by water dielectric transmission. The typical discharge voltage and current waveform are as shown in fig. 2. The total voltage of the discharge gas is 1.8 atm and the gram molecular ratio is HCl:XE: He=0.2:4:95.8. The discharge current is tested by a specially designed Rogowski coil, the voltage is measured by a resistance voltage divider and the two are recorded by an imitation OK-19M2 high pressure oscillograph. These results can calculate the gas discharge resistance in the discharge quasi-steady state process and in the discharge chamber as about 0.2-0.3 Ω . When in a typical laser mixed gas of HCl/Xe/Ne, the current and voltage waveforms are about the same and the impedance values belong to the same quantitative level.

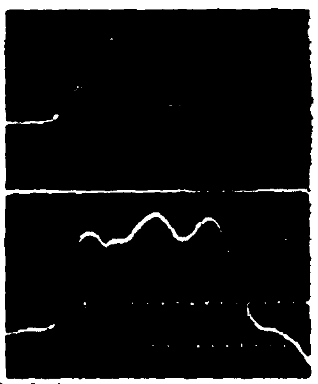


Fig. 2 The Discharge Chamber's Discharge Voltage (Above) and Discharge Current (Below) Change With the Time

In experiments, it was found that if there was no x-ray ionization in this device to carry out discharge, then the discharge was very non-homogeneous and laser output was not

observed. Therefore, well-tuned trigger coupling causes the moment the discharge exists in the x-ray preionization effect to be an important link. Fig. 3 presents synchronized photos of the x-ray diode's cathode voltage and discharge voltage when under normal operating conditions. Synchronized regulation is completed by means of regulating the coupling parameters (i.e. inductance L) in the pulse charged loop.

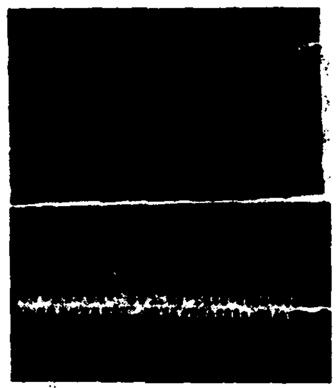


Fig. 3 Synchronized Photos of the X-Ray Diode's Cathode Voltage (Above) and the Laser Chamber's Discharge Voltage Which Changes With the Time

3. XeCl*3080Å Laser Output

We obtained relatively high laser energy density XeCl*3080Å output quite easily. Experiments showed that when Ne was used to replace He as the dilute gas results were better.

This test equipment obtained laser output in excess of 1.2J (about 5-6J/minute). Its test conditions were 4.75 atm pressure, the gas gram molecular ratio was HCl:Xe:Ne=0.06;0.78;99.16, the electrode distance was 2.0cm, the output coupling used a plate melted quartz lens with unplated film and a JN-1 laser energy meter was used (matching the JNK-1 amplifier). Under a laser output level of 1 joule, the laser energy ablated a white spot

on the black phase paper located near the window. Fig. 4 gives the output energy changes following the water dielectric transmission line's pulse charging voltage. Based on the current and voltage test values, the estimated laser efficiency was 2.0%.

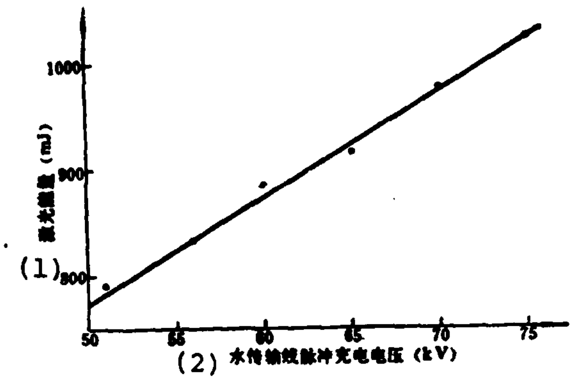


Fig. 4 The XeCl*3080Å Laser Output Energy Changes With the Water Transmission Line's Pulse Charging Voltage

Key: 1. Laser energy (mJ)
2. Water transmission line's pulse charging voltage (kV)

Fig. 5 gives the changes of the laser energy following the gas pressure of the discharge gas. Its test conditions are a gas gram molecular ratio of HCl:Xe:Ne=0.06:0.79:99.15, a water transmission line pulse charging voltage of 69kV and under 4.5 atm pressure there is still no energy saturation. Under high gas pressures, we can attain relatively good preionization results with x-rays. Because of this, there is also very great potential for further raising the XeCl*3080Å laser energy density.

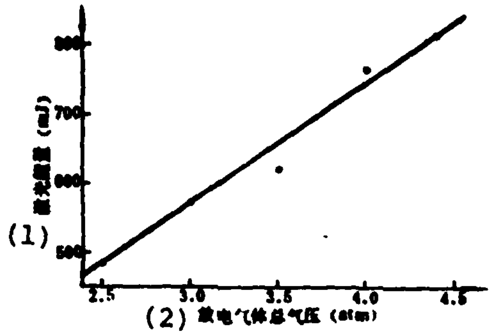


Fig. 5 The Laser Output Energy Changes With the Total Gas Pressure of the Discharge Gas

Key: 1. Laser energy (mJ)
2. Total gas pressure of the discharge gas (atm)

Measurements of the laser output waveform indicated that the laser pulse width (FWHM) was about 50ns and the peak power can reach 20MW. Fig. 6 gives the waveform of the laser output power which changes with the time. When measured, the total gas pressure in the device was 1.8 atm pressure, the gram molecular ratio was HCL:Xe:He-0.3:5:94.7 and the laster output was at the 0.1 joule quantity level. When the laser output energy is relatively high, the top part of the waveform has a flattening tendency.

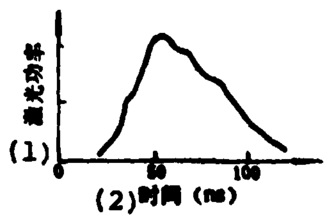


Fig. 6

Fig. 6 Output of XeCl*3080Å Laser

Key: 1. Laser power
2. Time (ns)

Fig. 7 shows an output spectrum photograph of the total gas pressure of the XeCl* laser under 3 atm.

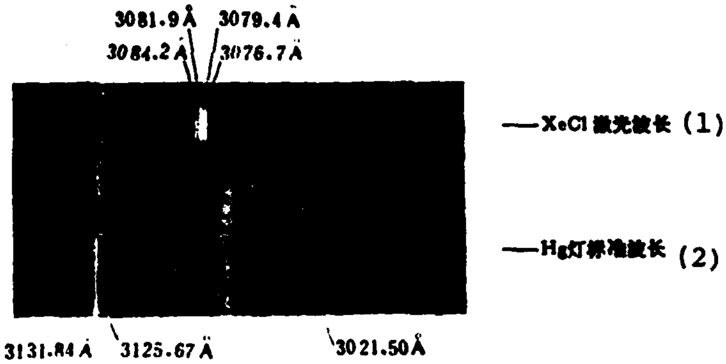


Fig. 7 Laser Output Spectrum of XeCl*3080Å High Gas Pressure Discharge

Key: 1. XeCl laser's wavelength
2. Hg lamp's standard wavelength

This is photographed with a WPG-1 plane grating spectograph. Its strongest ray wavelengths are mainly 3084Å, 3081.9Å, 3079.4Å and 3076.7Å. These correspond to 0-3, 0-2, 0-1 and 0-0 radiative transitions of XeCl*B → X.

References

[1] Koshima Seichu and Fujimoto Ryosan, Papers of the Electricity Institute, Vol. 98-C, No. 4, p. 133, 1978.

[2] S. Sumida, et al., Appl. Phys. Lett., Vol. 33, No. 11, p. 913, 1978.

[3] Shao-Chi Lin, et al., Appl. Phys. Lett. Vol. 34, No. 8, p. 505, 1979.

[4] S. Sumida, et al., The Review of Laser Engineering, Vol. 7, No. 3, p. 297, 1979.

PULSE WIDTH OF EXCIMER LASER*

by Lei Shizhan
(Shanghai Institute of Optics and Fine Mechanics, Academia Sinica)

Abstract

Based on the laser oscillation requirements, this paper discusses the conditions for increasing the laser pulse width of the excimer laser. In principle, the excimer laser can operate continuously but at present it is still not possible to attain excimer laser with continuous output.

I. Preface

The excimer laser is a new device which has rapidly been developed over the last few years. Because its energy conversion efficiency and power can reach high levels, it will be applied in many areas. For example, as an ultraviolet light source with high intensity or as a light pump source of a dye laser replacing a flickering lamp; it is also a very valuable light source in high resolution spectrum, isotopic ionization, gas trace element analysis as well as chemical reaction kinetic and photochemical research. Thus, excimer lasers have been given a good deal of attention.

At present, the many excimer lasers which have been researched and utilized are devices which use inert gas halide compounds (such as ArF, KrF, XeCl etc.) as the working substances. Quasi-molecules are excited state inert gas atoms formed by gas

*Received November, 1980, revised and finalized April, 1981.

discharge excitation. A collision complex is produced within the atomic state halide atoms. The ground state of the quasi-molecules is a weak bound state or repulsion state and it produces dissociation in a molecular vibration time (typical value is 10^{-13} seconds). Therefore, it can actually be said that quasi-molecules do not have a true ground state. It can be deduced from this that the excimer laser very easily realizes energy level particle number reversal between its excited state and ground state. Moreover, it can completely avoid the "bottle neck effect" encountered by the nitrogen particle and copper steam lasers. The light pulse width of the laser output can be large or small and can even operate with continuous waves. This is another outstanding feature of the excimer laser. However, the output's light pulse width of the presently used excimer laser is generally very narrow; only within ten to several ten millimicroseconds. What is the reason for this? Below we will use the XeF* excimer laser as an example to discuss this problem.

II. Fundamental Equations

The major process of forming quasi-molecules in inert gas and halide gas compound gas discharges is as follows:

$$
\begin{aligned}
&\bar{e} + Ar \xrightarrow{\sigma_{Ar^*}} Ar^* + e \\
&Ar^* + Ar + M \xrightarrow{k_1} Ar_2^* + M \\
&Ar^* + Ar \xrightarrow{k_9} Ar_2^* \\
&\bar{e} + Xe \xrightarrow{\sigma_{Xe^*}} Xe^* + e \\
&Xe^* + Xe \xrightarrow{k_{13}} Xe_2^* \\
&Ar^* + Xe \xrightarrow{k_6} Ar + Xe^* \\
&Ar_2^* + Xe \xrightarrow{k_{12}} Ar + Xe^* \\
&Xe^* + F_2 \xrightarrow{k_{14}} XeF^* + F \\
&XeF^* \xrightarrow{1/\tau_s} XeF + h\nu \\
&XeF^* + F_2 \xrightarrow{k_{21}} XeF + F + F \\
&Ar_2^* \xrightarrow{1/\tau} Ar_2 + h\nu
\end{aligned}
\qquad (I)
$$

In the equations, $\vec{e}$ expresses the fast moving electrons; e expresses the slow moving electrons; A* expresses the A atoms or molecules located in the excited state; σ^*_{Ar} and σ^*_{Xe} express the excitation sections of the electron collision excited Ar atoms and Xe atoms; k_i expresses the velocity constant of the corresponding process; τ_i expresses the self-excited radiation life time of the molecules; M is the Xe atoms or Ar atoms and F_2 atoms in the mixed gas; h is the Plank constant; v is the optical wave frequency of the radiation.

When in excited emission intensity $I \approx 0$, the density of quasi-molecole XeF* changes with the time and is expressed by the following set of equations

$$\frac{d}{dt}[Ar^*]=\sigma^*_{Ar}n_e v_e f(t)[Ar]-(k_3[Ar]^2+k_4[Xe]+k_9[Ar])[Ar^*] \qquad (1)$$

$$\frac{d}{dt}[Ar_2^*]=(k_3[Ar]^2+k_9[Ar])[Ar^*]-k_{12}[Xe][Ar_2^*]-\frac{1}{\tau_1}[Ar_2^*] \qquad (2)$$

$$\frac{d}{dt}[Xe^*]=\sigma^*_{Xe}n_e v_e f(t)[Xe]+k_4[Ar^*][Xe]+k_{12}[Ar_2^*][Xe] - (k_{13}[Xe]+k_{14}[F_2])[Xe^*] \qquad (3)$$

$$\frac{d}{dt}[XeF^*]=k_{14}[F_2][Xe^*]-\left(\frac{1}{\tau_2}+k_{21}[F_2]\right)[XeF^*] \qquad (4)$$

In the equations, A expresses the density of the A atoms or molecules; n_e is the electron density; v_e is the transition rate of the electrons ; f(t) is the normalized current pulse function. When the discharge current pulse is the shape shown in fig. 1, we have

$$f(t)=\begin{cases} t/\Delta t_1 & t<\Delta t_1 \\ 1 & t>\Delta t_1 \end{cases}$$

In the equation, t is the discharge time; Δt_1 is the electric pulse's front end rise time; Δt_2 is the discharge duration.

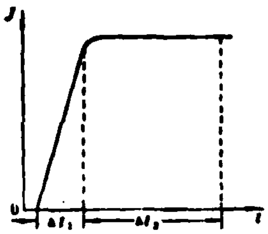


Fig. 1 Relationship of Discharge Current and Time

III. Results and Discussions

By combining and solving equations (1)-(4), we can obtain the following results:

(1) When $\Delta t_1<\Delta t_2<\frac{1}{\tau_2+k_{31}[F_2]}$, that is when the discharge current 's pulse duration is shorter than the relaxation time of quasi-molecules XeF*, the density of quasi-molecules Xef* is

$$[XeF^*]\approx k_{14}[F_2]\frac{(b_1+b_2)\Delta t_1}{a_1a_2}(a_2\Delta t_2) \tag{5}$$

(2) When $\Delta t_2>\frac{1}{\tau_2+k_{31}(F_2)}$, that is when the discharge current's duration is much longer than the relaxation time of quasi-molecules XeF*, the density of quasi-molecules XeF* is

$$[XeF^*]=k_{14}[F_2]\frac{(b_1+b_2)}{a_1a_2}\Delta t_1 \tag{6}$$

In the formula

$$b_1=\frac{v_e n_e[Ar]\sigma^*_{Ar}}{\Delta t_1}, \qquad b_2=\frac{v_e n_e[Xe]\sigma^*_{Xe}}{\Delta t_1}$$

$$a_1=k_{13}[Xe]+k_{14}[F_2], \qquad a_2=\tau_2+k_{22}[F_2]$$

The necessary condition for producing laser oscillation is the need for the gain coefficient to be greater than the loss which requires fulfillment of the following unequal formula

$$\sigma[XeF^*]>\left(\frac{a_2}{c}+\frac{a}{l}\right) \qquad (7)$$

In the formula, the first item on the right side is the loss produced by the self-radiation and collision relaxation of the quasi-molecules XeF*. The second item is the loss caused by the resonant cavity. σ is the excited emission section of the quasi-molecules XeF*; a is the loss of the reflector; l is the length of the resonant cavity; c is the velocity of light.

When it is required that the laser continually operate, that is be equal to discharge duration $\Delta t_2>\frac{1}{\tau_2+k_{22}[F_2]}$, we can obtain the following relationship from formulae (6) and (7)

$$\sigma n_e v_e(\sigma^*_{Ar}[Ar]+\sigma^*_{Xe}[Xe])>\left(\frac{a_2}{c}+\frac{a}{l}\right) \qquad (8)$$

We can use the following approximation formula to calculate discharge current density J_e

$$J_e\approx e v_e n_e \qquad (9)$$

In the formula, e is the electron charge. Therefore to attain continuous operation, continuous gas discharge threshold current density J_{eth} must reach the following level

$$J_{eth}>\left(\frac{a_2}{c}+\frac{a}{l}\right)\frac{1}{e\,\sigma(\sigma^*_{Ar}[Ar]+\sigma^*_{Xe}[Xe])} \qquad (10)$$

If the total gas pressure is 4 atm pressure, the fluorine gas pressure is 3 torr, the ratio of argon gas pressure and fluorine gas pressure is 10^3, a =5x10^{-2} and l=50cm, based on the given numerical values of dynamic constants [1] k_i, σ, σ^*_{Xe}, σ^*_{Ar}

and τ_1, τ_2, substitution formula (10) obtains

$$J_{eth} > 5A/cm^2$$

We know from the above discussion that a laser such as the XeF* excimer laser does not have a "bottle neck effect", the pulse width can be very wide and can even operate continuously. The conditions are the requirement of maintaining relatively high discharge current density. However, the required current density J_{eth} numerical value can be satisfied under pulsed discharge conditions but it is very difficult for continuous gas discharge. This is because if the gas discharge method is used for excitation, such high current density will cause arc discharge. As soon as the gas discharge changes to arc discharge, the gas temperature rises radically causing rate constant k_i in reaction process (I) to enlarge which causes a_2 to enlarge. This in turn requires even higher discharge current density to be able to satisfy oscillation conditions. As a result, a viscious circle is created which finally causes the laser to stop oscillation. It is necessary to consider using very high current density for the mixed gas so as to not cause arc discharge. We can use an electron beam to excite and pump the laser. By using an electron beam with long pulse length to excite the XeF* excimer laser, we can obtain output of a light pulse width reaching $1 \mu s$. Nevertheless, it is necessary to maintain electron beam flow density J_e larger than $5A/cm^2$ for a longer period of time but at present it is still very difficult technologically to manufacture such a generator. Therefore, at present, it is still not possible to attain an excimer laser with continuous output.

References

[1] E.R. Ault, et al., Appl.Phys. Lett., Vol.27, No.7, p.413, 1975; M.Rokni, et al., IEEE, J. Quantum Electron, Vol.QE-14, No. 7, p. 464, 1978.

[2] L.F. Champagne, et al., Appl. Phys. Lett., Vol.30. No. 3, P. 164, 1977.

LMED

-8